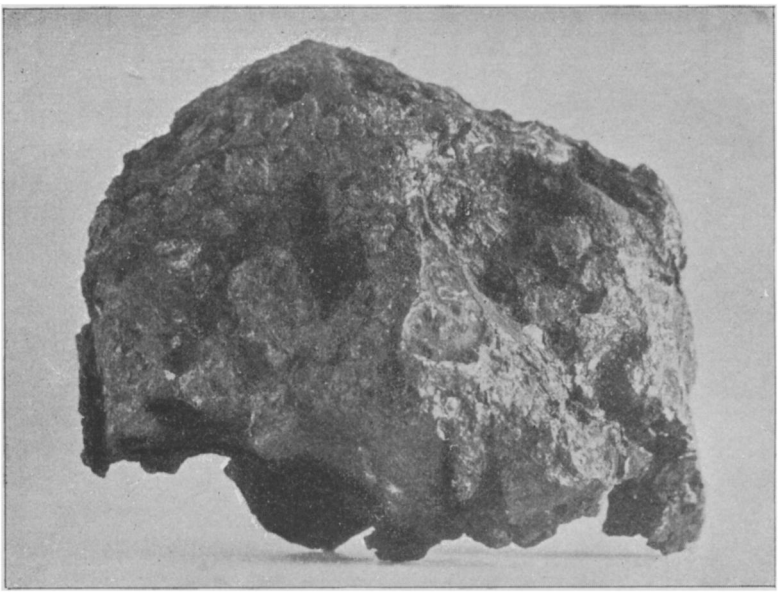

FIG. 1. — PREHISTORIC PALLASITE BEFORE CUTTING.
[Closely natural size.]

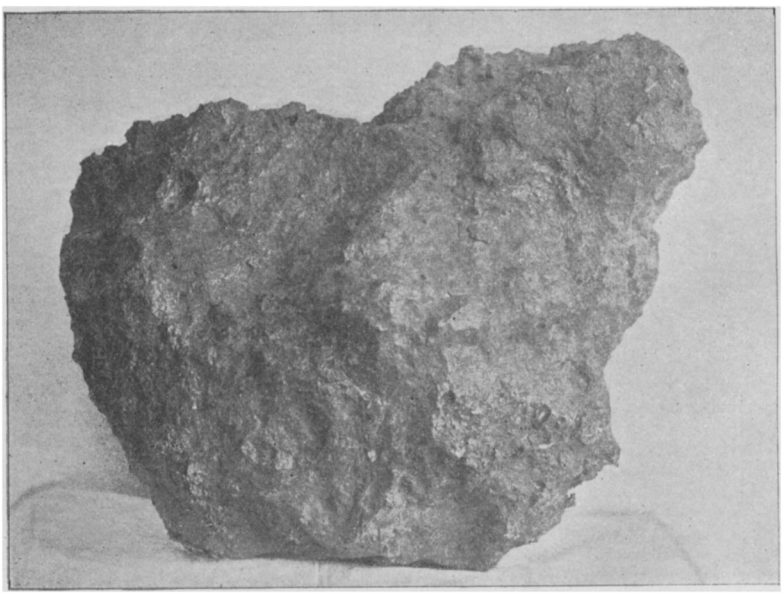

FIG. 2. — KIOWA COUNTY PALLASITE IN HARVARD CABINET.
[Reduced to one fifth in linear dimension.]

PROCEEDINGS

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VOL. XXVI.

PAPERS READ BEFORE THE ACADEMY.

I.

THE PREHISTORIC AND KIOWA COUNTY PALLASITES.

By Oliver Whipple Huntington, Ph. D.

Presented April 8, 1891.

In the Harvard Collection of Meteorites there is a small specimen of a pallas iron which is very highly prized as having the oldest authentic record. It is the main portion of a specimen which was found by Prof. F. W. Putnam in 1883 on the altar of Mound No. 4 of the Turner Group, in the Little Miami valley, Ohio. Therefore it is entered in the Harvard Catalogue as "Prehistoric." Ever since the acquisition of this Prehistoric specimen, specialists have been interested in trying to identify the main mass from which the smaller individual must have come. Figure 1, Plate I., shows the specimen of nearly its natural size as it came from the mound.

When the meteorite was first placed in the Harvard collection, the author of this paper made a careful study of the character and arrangement of the various constituents of the mass, thinking it possible that it might be identified with some of the pallas irons from the desert of Atacama, South America, which it appeared to resemble, thus indicating that the old builders of the mounds had visited that part of the world at some period in the remote past, and had brought away the

meteorite as a sacred object sent from Heaven. As is well known, meteorites have been worshipped in very early times, and, since this identical specimen was found on an altar, it must have been highly prized, if not an object of adoration. The result of the examination, however, showed that the Prehistoric iron differed in some of its most essential characters from all the South American specimens. It did, on the contrary, resemble most strikingly the famous Siberian meteorite from Medvedeva, Krasnojarsk, which has given the name of its finder, Pallas, to that class of meteorites in which the iron forms a continuous network enclosing grains of transparent green or yellow olivine. Notwithstanding the close resemblance of the Prehistoric and Pallas irons, as the localities were so widely separated, it seemed improbable that they could have come from one and the same original mass.

In 1880 a meteorite was found in Carroll County, Kentucky, and, since it contained iron and olivine, it was at once described as the probable origin of the Prehistoric mass, since no other olivine meteorite had up to that time been found in this country.* The diagrams, however, published at that time showed that the two irons did not even belong to the same class, since the Carroll County consisted of olivine surrounding small masses of iron, while the Prehistoric was a true pallasite, consisting of iron enclosing olivine; and in the further details of the specimens there appeared to be no resemblance whatever. This fact has since been admitted; and more recently, since some very remarkable pallas irons were found in Kiowa County, Kansas, these have been claimed to be the original masses from which the Prehistoric came.†

One of the Kiowa County specimens was obtained from Prof. F. W. Cragin of Washburn College, Iowa, for the Harvard Cabinet. On a hasty examination, the resemblance of the mass to the Prehistoric iron appeared very striking. A further study, however, brought out certain features which are quite unique and worthy of description, and at the same time led to the conclusion that the resemblance to the Prehistoric meteorite was not so remarkable as it at first appeared; while, on the other hand, a further comparison of the Prehistoric with the Pallas iron again showed the two to be almost identical, as already stated.

The mass from the Kiowa County find now in the Harvard collection weighs one hundred and twenty-six pounds. It has a more

* Am. Jour. Sci., Vol. XXXIII, March, 1887, p. 228.

† Science, Vol. XV. No. 384, June 13, 1890, p. 359.

or less ragged outline, as shown in Figure 2, Plate I., which is a reproduction from a photograph, much reduced; and the striking outline of a human profile on the right-hand upper corner suggests the possibility that it might have been taken for an image of a god. Its dimensions are, length fifteen and a half inches, height twelve and a half inches, thickness ten inches. The exterior is deeply pitted, and shows signs of fusion, as if the specimen had reached the earth as a complete individual. Its internal structure consists throughout of a continuous network of iron, enclosing grains of more or less transparent green olivine. In certain portions, as would be expected, the olivine has become somewhat altered by weathering. One spur of the mass has been sliced, and the slabs show in the unexposed portions beautiful crystals of transparent green olivine. The surface exposed by sawing has an area of about ninety square inches, and exhibits some striking variations in its different parts. Some of the olivine appears in two distinct zones, the outer portion being so dark colored that at first sight it appears by reflected light to be black, and on the large section just mentioned this apparent dark olivine occurs most abundantly around the outer edges of the section, extending in some cases an inch or more into the interior of the mass. But it is still more noticeably distributed along a crack, which extends irregularly through the mass and divides the large cut surface into nearly equal halves. This crack is followed throughout its entire length, a distance of ten inches, by an abundant deposit of the dark olivine, the grains being separated from one another by deposits of troilite, while at a short distance from the crack on either side occurs transparent green olivine, wholly distinct from the dark variety, and here the troilite is less abundant. In the original description of the Kiowa County meteorites the peculiar appearance of the olivine is described as follows: "Many of the olivine crystals are in two distinct zones, — the inner half a bright transparent yellow, the outer a dark brown iron olivine. In reality this dark zone is an intimate mixture of the troilite and the olivine, as the analysis of Mr. Eakins and a microscopical examination of the crystals by Mr. J. S. Diller of the United States Geological Survey fully proved."* This description, however, does not notice what is perhaps the most striking feature of the dark olivine, namely, that it is so strongly magnetic that lumps of considerable size will readily jump to an ordinary horseshoe magnet. Since olivine is not attracted by the magnet, and most troilite only feebly so, and pure troilite not at all, it seems hardly pos-

* Science, Vol. XV. No. 384, June 13, 1890, p. 361.

sible that a simple mixture of the two should become as magnetic as magnetite.

On referring to the analysis made by Mr. L. G. Eakins in the laboratory of the United States Geological Survey, it appears that the composition of the dark olivine somewhat resembled that of hyalosiderite, — a variety of olivine which might be strongly magnetic. The question then arose as to whether the zone of dark olivine owed its magnetism to the composition of the olivine, or whether it was due to an admixture of a magnetic variety of sulphide of iron.

It was very difficult to obtain pieces of the dark olivine free from veins of troilite, but with sufficient care quite large fragments could be picked out, which under the microscope showed a somewhat resinous lustre, and a color varying from black and opaque to transparent red and yellow or colorless, but with no signs of any characteristic grains of troilite. After grinding the material to powder, the darker specks could be separated by the magnet, leaving the light transparent part. The magnetic portion thus selected would gelatinize with acid, but also invariably would give the reaction for sulphur, although showing no other characteristics of troilite even when examined in a thin section under the microscope. The same material was found in the Pallas and Prehistoric specimens, though of a still darker color and giving a far stronger sulphur reaction. When it became evident that the sulphur was a constant accessory of the magnetic olivine, it precluded the possibility of the olivine being a distinct variety, like hyalosiderite.

The distribution of the dark olivine mainly near the exterior of the mass and along the crack, with only occasional patches in the interior, would suggest its being an alteration product. This appeared still more probable after examining a thin section of one of the dark olivine crystals. It was seen at once that the crystals of olivine were intact except for a dark deposit along the cleavage cracks. Where the dark portion bordered on the green, the olivine was somewhat discolored, red or yellow, but evidently it had not undergone any change from weathering. It seemed more as if the dark portion had been fused and drawn into the cracks of the olivine. Experiments were therefore made to see what the effect would be of fusing the olivine and troilite of the Kiowa County pallasite, and it was found that, if non-magnetic troilite and crystals of transparent green or colorless olivine were heated together out of direct contact with the air, and the temperature raised to near the melting point of the olivine, the troilite would turn black, become strongly magnetic, and permeate all the

cracks of the olivine, while portions of the olivine near the troilite changed to various shades of red and yellow, the darker portions being strongly magnetic. Otherwise, the olivine retained all its former characteristics of crystalline form and cleavage. Moreover, portions of the artificial product could be selected which would so closely resemble similar specimens from the meteorite, that, after they had been once mixed together, they could not be distinguished. This seemed to show conclusively that the dark outer zone of olivine is a mixture of troilite and olivine only in the sense above indicated.

On an examination of the slabs of this iron by etching, certain other features appear which in part connect it most closely with the Pallas and Prehistoric irons, and in part are peculiar to the Kiowa County iron alone.

The olivine crystals are in the first place surrounded by a deposit of what is probably the purer iron. This border is of varying thickness, not generally exceeding one or two millimeters, and occasionally wholly disappearing. Parts of the border are most beautifully marked by innumerable Neumann lines, microscopically fine, and so numerous as to give it a silvery appearance and a brilliant lustre that at once strike the eye. Between this iron border and the olivine come masses of troilite, and these fill the space between the olivine crystals, and thus have the same kind of outline as the iron network, and appear as a continuation of the network. Troilite, however, also occurs in small nodules in the iron itself, and sometimes again as the central portion of an olivine crystal. Such a quantity and distribution of the troilite appear in no other meteorite except the original Pallas. A further resemblance between these last named meteorites is brought out in the occurrence of schreiberseit. This mineral is at once distinguished by the eye from the troilite, on account of its brighter lustre, granular structure, and more silvery color. Furthermore, it is harder, and strongly magnetic. The schreiberseit occurs in close connection with the troilite, usually in patches coming between it and the iron, but frequently portions of schreiberseit project into the iron itself, sometimes in elongated masses reaching a length of half an inch or more. In such cases the iron bordering on the schreiberseit has the same characters as when in contact with the olivine crystals, as just described.

The main portions of the iron show a most perfect crystallization, which is very beautifully brought out by etching. Crystal plates start out from the iron border already mentioned, and reach back through the whole extent of the interior iron. The figures thus produced are

finer and sharper than those of any other specimen in the Harvard collection. They consist of thin plates closely packed together, not exceeding half a millimeter in thickness, but sharply defined by their border lines of bright nickeliferous iron. These plates as seen in section exhibit beautiful Neumann lines, the same as the border iron previously described, and appear to be of a piece with it. A slight suggestion of a similar crystallization is given by the Pallas iron, but the specimen at the author's disposal is not large enough for a thorough comparison. In cutting the large Kiowa County mass, the saw passed through portions of iron of considerable area, and in etching one of these nodules the plates were brought out in their greatest perfection.

The appearance of the Widmanstättian figures is best shown by Figure 3, Plate II., which is printed directly from the iron. Unfortunately, the printing does not bring out the Neumann lines on the border iron, though they are suggested in some parts of the illustration, but the general character and distribution of the Widmanstättian plates is very fairly shown. One peculiarity, however, does not exist in the slab from which the plate was printed, and though it only occurs in two or three places, yet, as it has not been observed in any other meteorite, it is worthy of note in this connection. Ordinarily in the pallasites the olivine is surrounded by a layer of iron, as if the iron had been deposited on the olivine as a nucleus; but in some of the specimens of the Kiowa County the plates of iron which form the Widmanstättian figures actually project into the olivine crystals, as if the two had solidified simultaneously. It is common here, as in other pallasites, for little plates of iron to separate two crystals of olivine; but in the specimen under discussion there are cases where the Widmanstättian plates cross the natural boundary line of the iron and project out into the olivine crystals, and intersect each other at the octahedral angle apparently wholly independent of the presence of the olivine. Occasionally, too, a little plate of iron is seen isolated from the rest, and in the very centre of a nodule of olivine. No cases were observed where the Widmanstättian plates actually cut through the olivine crystals so as to connect with the iron on the opposite side, but they projected into the crystals several millimeters.

Finally, by far the most striking and characteristic feature of the Kiowa County pallasite is the abundant occurrence of chromite. This mineral is easily confused with the dark olivine described in an earlier part of this paper, since the mode of occurrence is exactly the same, and on a polished surface the only difference is that the chromite has a more metallic lustre, and is more opaque. Chromite is widely dis-

tributed through the meteorite intimately mixed with olivine, although in some cases large crystals of clear green olivine are to be found embedded in the chromite. In several places masses of nearly pure chromite of more than an inch in diameter appear, intersected by the network of iron with its accompanying troilite and schreiberseit, the chromite largely replacing the olivine. This mixture of chromite and olivine appears as a whole perfectly black and opaque, breaking with a subconchoidal fracture, and having a brilliant submetallic lustre. It is strongly attracted by the magnet, and differs most markedly from the dark olivine before described in being perfectly opaque, and the powder is dark brown or black where in the former case it was gray.

SECTION OF OLIVINE CRYSTAL SHOWING CHROMITE.

A perfect octahedron with an axis of about two millimeters was broken out from one of these masses, but in most cases the chromite took the form of the olivine. The cause of this will be evident by reference to the accompanying figure, which represents a microscopic section of a black perfectly opaque and strongly magnetic lump of this material, the diagram having been drawn from the microscope by means of a camera lucida. It will be seen at once that, instead of its being a homogeneous substance, it proved to be a section of a transparent crystal of olivine which had had all its cleavage cracks well filled with chromite. Under the microscope, the chromite is still perfectly opaque even in such a thin section, and has a noticeably metallic lustre, with no gradual change from dark to light, as was the case in the other variety of dark olivine.

On examining the specimens of the Prehistoric and Pallas irons in the Harvard collection, no chromite was found, though of course the absence of it in those particular specimens cannot be taken as conclusive evidence of its absence in all; but it may be safely said that it would be impossible to select equally large specimens from the Kiowa County iron which would be free from this mineral.

In comparing the three pallasites, Prehistoric, Krasnojarsk, and Kiowa County, we obtain the following results.

First. All three have the dark olivine, strongly attracted by the magnet, appearing near the outside of the specimen, and frequently surrounding the clear green variety.

Secondly. All have a striking border of iron surrounding the olivine, showing a silvery sheen from the innumerable Neumann lines.

Thirdly. All show signs of Widmanstättian figures in the groundmass of the iron.

Fourthly. The Krasnojarsk and the Kiowa County both have a large quantity of troilite between the crystals of olivine, and also patches of schreiberseit between the troilite and the iron, and occasionally included by the iron. This same character appears, but in a much less degree, in the Prehistoric.

Fifthly. The Krasnojarsk and Kiowa specimens further show a much larger proportion of iron than the Prehistoric, though closely resembling each other in that respect. Figure 4, Plate II., shows a slab of the Prehistoric, printed directly from the iron.

Sixthly. The Kiowa County iron shows a very striking and far more perfect crystallization than any other pallasite heretofore described, so that if Widmanstättian figures can be used at all as a means of distinguishing irons of different falls, then the Kiowa County is distinct from any meteorite thus far described.

Lastly. The Kiowa County pallasite contains large quantities of chromite distributed through it, completely permeating large masses of the olivine, but no chromite is to be found in the Prehistoric iron or in the specimens of the Pallas meteorite in the Harvard collection.

In the description of the Kiowa County iron already referred to, the analysis and specific gravity of the olivine of the Prehistoric are compared with those of the Kiowa County as a proof of the identity of the two; but a glance at the following table will show that the analysis of the Kiowa County olivine shows a still closer resemblance to the olivine from the Pallas meteorite, and also that from Mount Etna.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	H_2O	Total.	Sp. Gr.
Kiowa County	40.70	tr.	0.18	10.79	0.02	0.14	48.02		99.85	3.376
Etna	41.01	0.64		10.06	0.20		47.27	1.04	100.22	3.334
Pallas	40.83	tr.		11.53		0.29	47.74		100.39	3.334
Vesuvius . . .	40.35			12.34			46.70		99.39	
Mt. Somma .	40.08	0.18		15.26		0.48	44.22		100 24	
Prehistoric . .	40.02			14.06		0.10	45.60		99.78	3.336
Atacama . . .	36.92			17.21		1.86	43.90		99.89	3.330
Antuclo, Chili	40.70			19.60			39.70		100.00	

Furthermore, since the specific gravity of olivine only varies from 3.33 to 3.56, it is not surprising that the specific gravity of the Kiowa County and Prehistoric olivines should be so nearly alike; but it will be seen by the above table that it differs from the Prehistoric more widely than the latter differs from the other volcanic olivines. The above table could be largely extended, but enough is given to show that the olivine from the Kiowa County meteorite more closely resembles some modern volcanic products and the original Pallas meteorite, than it resembles the Prehistoric. Furthermore, when the difficulty of obtaining an average sample of meteoric material for analysis is borne in mind, it will be seen how useless it is to compare the analyses as a proof of the identity of any meteorites, and particularly the olivine ones. But the same difficulties lie in the way of giving undue weight to the etched figures or structure of a small specimen. For instance, the well known meteorite that fell at Estherville, Emmet County, Iowa, is made up largely of olivine, the iron in most specimens not forming a continuous network; yet portions can be selected almost entirely free from iron, and others where iron forms much the larger part. Figure 5, Plate II., is printed directly from an iron nodule taken from the Estherville meteorite, and placed here for comparison with the similar mass shown in the Kiowa County slab. It will be seen at once that the etched surfaces of the two irons show utterly different Widmanstättian figures. Yet the Estherville specimen does not exhibit any of the peculiar characteristics which we are in the habit of associating with that iron, and the slab from which Figure 5 is printed might be mistaken by an expert for at least half a dozen typical Widmanstättian irons, while the olivine iron to which it really belongs would be one of the last to be compared with it.

A similar feature appears even more strikingly on comparing the specimens found in Kiowa County. The largest of these has throughout the structure typical of the pallasites, but several of the smaller

masses consisted wholly of iron exhibiting a highly developed crystalline structure, and in one at least, which passed into the possession of Mr. Howell of Rochester, N. Y., one end of the mass was pure iron while the rest was pallasite. We give a figure of an etched slab of this last mass, Figure 6, Plate III., which is printed directly from the iron. When first found, one was inclined to believe that the irons and the pallasites so closely associated over an area hardly exceeding sixty acres could not have come from the same fall, and this opinion seemed supported by the greater coarseness of the Widmanstättian figures on the sections of the isolated irons; but such association as is exhibited in Figure 6, Plate III., makes the intimate connection evident, and gives evidence in favor of the theory which regards meteorites as resulting from intensely violent volcanic outbursts on the surface of a planet so far cooled that the still melted nucleus was coated with an earthy crust, through which the surface water as it condensed percolated to the molten interior. By the resulting violent eruptions, of which we can form only a faint conception from terrestial volcanoes of the present day, this crust would be fissured on long lines of least resistance, and volcanic bombs thrown into space beyond the sphere controlled by the planet's attraction. Those bombs which came from the zone of contact of the melted iron with the crust would naturally have the structure of pallasites, mixed with masses consisting wholly or chiefly of metal. The specimen from which Figure 6 is printed seems to furnish the link needed to connect the stony with the iron meteorites, and if the iron portion be compared with the iron in Figure 3, Plate II., from the same fall, it will be seen of how little value the appearance of the etched surfaces would be in identifying selected portions from the two slabs.

The result of this discussion merely shows the impossibility of identifying these pallasites, which at first sight appear so much alike. If the Kiowa County specimens are accepted as identical with the one from the mounds, then both must be the same as the one from Krasnojarsk, Siberia, without further question; but the striking occurrence of chromite in such unusual quantity in the Kiowa County mass would seem sufficient to place that by itself, while leaving the close resemblance between the Prehistoric and Krasnojarsk pallasites as yet unexplained.

The question naturally arises as to the possibility of the mound builders having actually brought the Prehistoric specimen from Siberia as a sacred object. This is scarcely probable. It is well known from the writings of various authors that the inter-tribal traffic of the

American Indians was very great, and that they occasionally made journeys completely across this continent, as, for instance, the journey of Moncacht-Apé,* together with others fully as remarkable and perhaps more authentic. Moreover, Margry writes: "Il nous disoit, dans la Bibliothèque du Roy, à feu M. Thevenot et à moy, qu'il estoit dans la mesme opinion, et cela d'autant plus que le Père Martini luy avoua, en la Chine, qu'il avoit confessé en espagnol une femme Mexiquaine, qui, ayant esté enlevée esclave au Mexique, estoit arrivée de pays en pays, de nation en nation et d'esclavage en esclavage, en la Chine, par terre, sans avoir passé qu'un petit détroit de mer, et cette histoire est rapportée dans le cinquiesme volume in-8° en italien, avec figures de Giro del Mondo, du docteur Gemelli, Napolitain, arrivé depuis un an à Naples, d'où je me suis fait venir ce livre en six volumes." †

If this could be believed, it might be possible that the Prehistoric iron had found its way across Behring Straits till finally it was collected, with the other relics from all parts of this country, on the altar of Mound No. 3 of the Turner Group in Little Miami Valley, Ohio. Unfortunately for this solution, Prof. F. W. Putnam considers that the people who built the mounds came from the south. That they may have at one time had communication with China seems probable from the frequent occurrence of specimens of jadeite among their implements, and from the fact that in most cases the jadeite implements have been subsequently cut up into ornaments, while the nephrites have been left intact, showing that the former must have become more and more rare and highly prized as they were passed down through successive generations.

Provided that the original owners of our Prehistoric meteorite had associations with China, still there is no reason for supposing that they had any communication with Siberia. Nevertheless, can it be considered much more remarkable that a Siberian meteorite should be found on an altar in an Ohio mound, than that a pipe of the red indurated clay, found only on the Pipe Stone Branch of the Little Sioux River of the Missouri, should be picked up on the banks of the Rio de la Plata in South America, and several more in New England? ‡

The only other explanation of the close resemblance between the Prehistoric iron and the original Pallas would be that they were two portions of the same meteoric outburst which fell at remote distances

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* Proc. Am. Antiquarian Soc., April 25, 1883.

† Découvertes de l'Amerique Septentrionale, 1614–1754, Vol. VI. p. 173.

‡ Long's Expedition, Vol. I. p. 31.

from each other, possibly in two hemispheres, though as yet the most distant places in which the same meteorite has been identified are Mexico and Kentucky.*

The subject is an interesting one, and could be discussed at much greater length than the limits of this paper will allow, but the only object of this discussion has been to show that there is a wonderfully close resemblance between the Prehistoric and Pallas iron, and that, though the Prehistoric resembles the Kiowa County far more closely than it does the Carroll County, yet there is no reason for regarding them as identical.

In this discussion the Harvard mass of the Kiowa County find has been compared with another specimen from the same, described in a paper previously quoted as if the two were identical, and, in closing, the author would mention that he has had the opportunity of examining the various specimens in mass, and also the cut slabs placed side by side, and they are unquestionably the same.

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* Proceedings of this Academy, Vol. XXIV. p. 30, October, 1888.

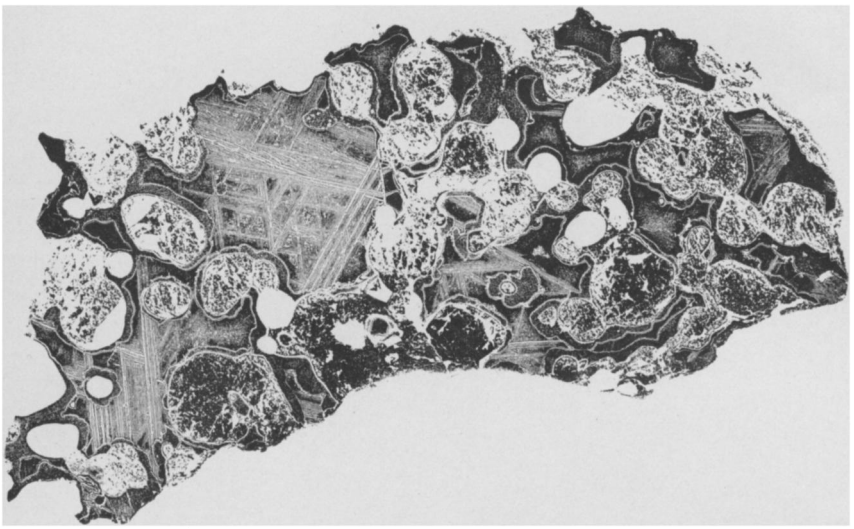

FIG 3. — KIOWA COUNTY, PRINTED DIRECTLY FROM THE SLAB.

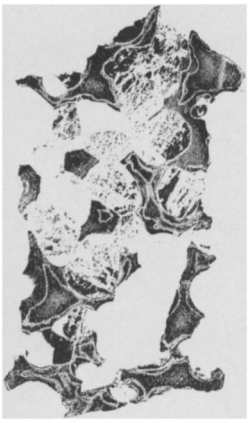

FIG. 4. — PREHISTORIC, PRINTED FROM THE IRON.

FIG. 5. — PRINTED FROM ESTHERVILLE NODULE.

FIG. 6. — SLAB OF KIOWA COUNTY IRON RECEIVED FROM WARD AND HOWELL.